Annual March of Daily Mean Temperatures at Honolulu

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THE PRESENT PAPER attempts to answer objectively the recurring question as to when the warmest and coldest weather occurs at Honolulu. For basic data the "daily mean temperature," which is the arithmetic mean between the maximum and minimum temperatures recorded during the 24-hour day, was chosen. It is usually reported to the nearest whole degree, since the temperatures used for its computation are not reported in fractions of a degree. If the arithmetic mean ends in five-tenths of a degree, it is arbitrarily rounded to the nearest even degree, whether this involves rounding up or rounding down.

In 1931, Mr. John F. Voorhees, then meteorologist of the Honolulu office of the U. S. Weather Bureau, supplied me with averages of the daily mean temperatures for each of the 365 days of the year. These covered the 41-year period from 1890 to 1930, inclusive. I do not know where the instruments were located from 1890 through 1904. From 1905 to 1922 the records were made on the Young Hotel Building, 121 feet above the ground, and since 1922 on the Federal Building, 99 feet above the ground. The difference in stations is not significant for the present study since it compares the averages for each date of the year and does not compare data from earlier and later periods. Leap day has been omitted from consideration.

Mr. Harry T. Tanaka, a student at the University of Hawaii, working on N. Y. A. funds, tabulated the daily means for the 10-year period from 1931 through 1940, and I have added the data for the 7 years from 1941 through 1947, thus getting the average daily mean temperatures for each of the 365 dates for the 58-year period from 1890 through 1947. The averages were calculated to tenths of a degree and are given in Table 1 and are shown graphically in Figure 1.

A study of the data for the 53-year period from 1890 to 1942 was reported to the Hawaiian Academy of Science in 1943 (Palmer, Harold S., The Annual March of Daily Mean Temperature at Honolulu. [Abstract.] *Hawaii. Acad. Sci., Proc.* 1945: 3). For that study a number of ways of smoothing and otherwise treating the raw data were tried. The method finally chosen as most satisfactory was that of 7-day progressive means, and is used in the present study. The method is this: the values for seven consecutive days are added, the sum is divided by seven, and the quotient is used for the middle, or fourth, day of the seven. The resulting 7-day progressive means are given in Table 2 and are shown graphically in Figure 2.

THE COLDEST DATE

The data show that February 12, 13, and 14 have the lowest smoothed temperatures, namely 70.9° F. It is reasonable to suppose that February 13 is the coldest of the three, and this is confirmed by the fact that it is the coldest date among the unsmoothed data. Calculation of the smoothed values to hundredths of a degree further confirms this choice since the values for February 12, 13, and 14 are 70.92°, 70.91°, and 70.93°, respectively. It must be admitted that working to hundredths of a degree is unwarranted since the raw data were taken only to the nearest whole degree; but the calculation is given for what it may be worth.

A disagreement is found in the data for the 17-year period, 1931–1947, similarly

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TABLE 1

FIFTY-EIGHT-YEAR DAILY MEAN TEMPERATURES. AVERAGED, BUT NOT SMOOTHED

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1	72.5	71.3	71.8	72.5	74.2	76.1	77.2	78.3	78.2	78.1	76.3	74.1
2	72.0	71.6	71.5	72.4	74.0	75.9	77.3	78.0	78.5	78.1	76.0	74.0
3	71.7	71.8	71.7	72.6	74.2	76.2	77.4	78.1	78.5	77.8	76.0	73.8
4	71.6	71.4	71.2	72.4	74.1	76.1	77.5	78.3	78.5	77.4	76.2	73.8
5	71.7	71.5	71.4	72.3	74.0	76.3	77.2	78.5	78.5	77.4	75.9	73.8
6	71.6	71.5	71.3	72.6	74.0	76.3	77.2	78.6	78.2	77.4	75.9	73.5
7	71.8	71.5	71.4	72.5	74.2	76.2	77.4	78.4	78.2	77.7	75.4	73.6
8	71.7	71.3	71.3	72.4	74.6	76.2	77.5	78.4	78.5	77.3	75.2	73.3
9	71.7	71.2	71.4	72.6	74.4	76.3	77.6	78.4	78.7	77.3	75.6	72.9
10	71.4	71.1	71.1	73.1	74.2	76.5	77.7	78.3	78.4	77.2	75.6	73.1
11	71.7	71.2	71.2	72.8	74.5	76.6	77.4	78.3	78.4	77.4	75.4	73.2
12	71.6	70.9	71.2	72.8	74.7	76.7	77.5	78.3	78.3	77.2	75.2	72.7
13	71.3	70.5*	71.2	73.1	74.4	76.7	77.5	78.5	78.0	77.1	75.2	72.3
14	71.2	70.7	71.6	73.4	74.9	76.9	77.6	78.3	78.1	77.0	74.8	72.8
15	71.0	70.8	71.5	73.2	75.0	76.6	77.8	78.3	78.3	77.4	74.5	72.9
16	71.0	71.1	71.8	73.4	74.9	76.7	77.8	78.5	78.2	77.4	74.7	73.0
17	71.1	71.3	71.6	73.4	75.2	77.0	78.0	78.4	78.3	77.1	74.6	72.5
18	71.7	71.5	72.0	73.6	75.2	76.9	78.0	78.5	78.2	76.9	75.0	72.7
19	71.7	71.4	72.0	73.4	75.3	76.9	78.0	78.8†	78.1	77.0	74.8	72.8
20	71.2	71.4	72.1	73.1	75.4	76.8	78.1	78.2	78.1	77.0	74.4	72.8
21	71.3	71.5	71.9	73.3	75.5	76.8	78.0	78.4	77.9	76.9	74.1	72.7
22	71.3	71.8	71.9	73.5	75.4	77.0	78.0	78.5	77.6	76.5	74.2	72.6
23	71.6	71.6	72.1	73.3	75.5	77.0	78.0	78.5	78.0	76.5	73.8	72.7
24	71.3	71.9	72.2	73.6	75.5	77.2	78.0	78.5	78.1	76.5	73.8	72.5
25	71.2	71.9	71.9	73.8	75.7	77.1	78.1	78.4	78.3	76.5	74.0	72.2
26	70.9	71.5	71.8	73.9	75.5	77.2	78.1	78.4	78.1	76.5	73.6	72.4
27	71.1	71.4	71.6	74.0	75.6	77.3	78.2	78.4	77.9	76.7	74.2	72.4
28	71.1	71.1	71.7	74.0	75.7	77.5	78.2	78.4	77.8	76.2	73.7	72.3
29	71.0	......	72.2	73.7	75.8	77.2	78.2	78.3	78.1	76.2	73.8	72.5
30	71.3	......	72.2	73.8	76.0	77.2	78.2	78.3	77.8	76.5	73.7	72.1
31	71.3	......	72.1	......	75.9	......	78.1	78.4	......	76.6	......	72.3

*Coldest date. †Warmest date.

smoothed. The coldest dates in February for this period are the tenth, eleventh, and twelfth, with smoothed values of 71.6°, but there are colder dates in March, namely March 7 to 13, with smoothed temperatures of 71.5°, 71.4°, 71.3°, 71.3°, 71.4°, 71.4°, and 71.5°, respectively. The graph of the smoothed temperatures for the 58-year period (Figure 2) has a secondary trough from March 8 to 11, with 71.3° on the four days.

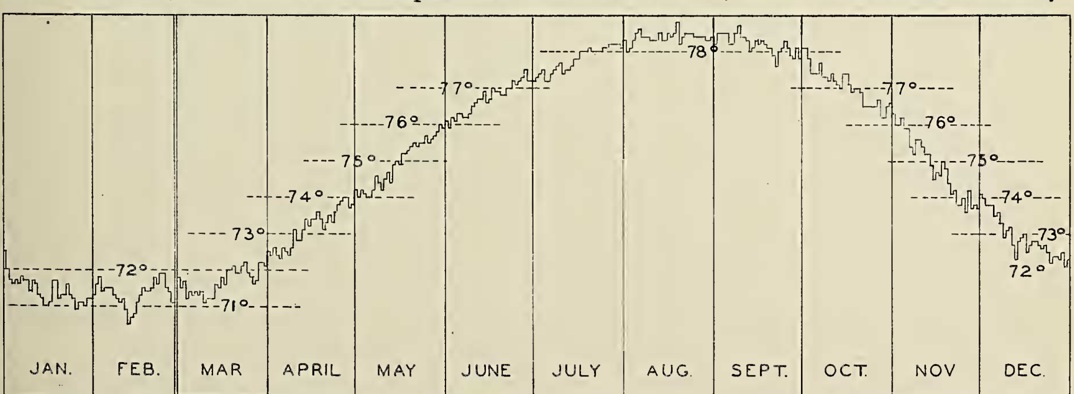

FIG. 1. Averages of daily mean temperature at Honolulu; not smoothed; 58 years, 1890 to 1947.

A POSSIBLE RHYTHM

From about January 10 to March 20 there are several fluctuations with ranges of about 0.6°. For most regions 0.6° would not be significant, but it might be significant for Honolulu where the conventional "mean annual range of temperature" is only 6.8° (78.3° — 71.5°) and the extreme range is only 38° (90° — 52°). Therefore a study was undertaken of the fluctuations in the first 3 months of each of the 18 years from 1931 to 1948. The value of 0.6° is about 9 per cent of the 6.8° mean annual range and is about 1.6 per cent of the extreme range. Inspection of Figure 2 shows troughs with center dates of Jaunary 16, January 28, February 13, and March 8 or 9. Eighteen sets of 7-day progressive means were computed for the first 3 months, one set for each of the 18 years. These means were plotted as 18 graphs, and were inspected to see to what extent there were troughs that coincided with one another and with the troughs of Figure 2.

In Figure 2 there are four more or less definite troughs and four or five more or less definite crests between January 1 and March 31. The 18 graphs for the 18 years show from three to six troughs and from two to six crests, their distribution being shown in the following tabulation.

Frequency of Numbers of Troughs and Crests per Year

I	II	III
2	0	1
3	5	2
4	5	5
5	7	6
6	1	4

I. The number of troughs (or crests) per year.
II. The number of years with the number of troughs indicated in I.
III. The number of years with the number of crests indicated in I.

The frequencies shown in the tabulation differ so much from the numbers of troughs and crests in Figure 2 that they make untenable the idea that some meteorological rhythm causes the troughs and crests of Figure 2.

Moreover, if there were some rhythmic cause that repeated in a significant number of the 18 years, we ought to find recurrences of troughs and crests on or about the same dates. A table was prepared with (a) the 84 days for which 7-day progressive means were calculated and (b) the 18 years as arguments. Each trough or crest was entered in the body of the table at the proper date and year. Only a few dates gave more than 3 years with either troughs or crests. January 5 with four crests and February 21 with five crests were the highest, but neither of these dates is noteworthy in Figure 2. January 21 had four troughs but also had one contradictory crest, and is moreover close to a crest in Figure 2. February 16, which follows by 3 days the trough of Figure 2, had three crests in the 18 years. The data for January 21 and February 16 definitely contradict the hypothesis of a rhythmic control.

Smoothed averages for the 41-year and the 17-year periods showed no exact coincidences of troughs and crests with one another, nor with the 58-year graph of Figure 2. So we conclude that there is no evidence of an annually recurring, rhythmic cause to explain the troughs and crests of Figure 2. No doubt the troughs and crests of graphs for single years are due to the influence of fronts related to highs and lows that pass near enough to affect Honolulu's weather. There certainly is no mystic relationship to the winter solstice.

THE WARMEST DATE

Selection of a warmest date is less simple because the smoothed values form a sort of plateau of 36 days, including 30 dates of 78.4°, with 2 dates a tenth of a degree lower and 4 dates a tenth of a degree higher. Among the 7-day progressive means for the 58-year data, we find 78.5° on August 16, 19, 20, 21, and 22, with 78.4° on August 17 and 18. The 7-day progressive means were subjected to a second, similar smoothing, which gave a series of five dates, August 18 to 22, with 78.5°. The middle date is August 20, which may therefore be taken as the warmest date.

TABLE 2
ANNUAL MARCH OF DAILY MEAN TEMPERATURES AT HONOLULU, 58-YEAR DATA, 1890–1947.
SMOOTHED AS 7-DAY PROGRESSIVE MEANS

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1	72.1	71.4	71.5	72.3	74.0	76.0	77.3	78.2	78.4	77.9	76.3	73.8
2	72.0	.5	.4	.4	.0	.1	.3	.2	.4	.8	.2	.9
3	71.9	.5	.4	.4	.0	.1	.3	.3	.4	.7	.1	.8
4	.8	.5	.5	.5	.1	.2	.3	.3	.4	.7	76.0	.7
5	.7	.5	.4	.5	.2	.2	.4	.3	.4	.6	75.8	.7
6	.7	.5	.4	.5	.2	.2	.4	.4	.4	.5	.7	.5
7	.6	.4	.3	.6	.2	.3	.4	.4	.4	.4	.7	.4
8	.7	.3	.3	.6	.3	.3	.4	.4	.4	.4	.6	.3
9	.6	.2	.3	.7	.4	.4	.5	.4	.4	.4	.5	.2
10	.6	.1	.3	.8	.4	.5	.5	.4	.4	.3	.4	73.0
11	.5	71.0	.3	72.9	.5	.6	.5	.4	.3	.2	.3	72.9
12	.4	70.9	.3	73.0	.6	.6	.6	.3	.3	.2	.2	.8
13	.3	.9	.4	.1	.7	.7	.6	.4	.2	.2	75.1	.9
14	.3	70.9	.4	.2	.8	.7	.7	.4	.2	.2	74.9	8
15	.3	71.0	.6	.3	74.9	.8	.7	.4	.2	.2	.9	.7
16	.3	.0	.7	.4	75.0	.8	.8	.5	.2	.1	.8	.7
17	.3	.2	.8	.4	.1	.8	77.9	.4	.2	.1	.7	.8
18	.3	.3	.8	.3	.2	.8	78.0	.4	.2	.1	.6	8
19	.3	.4	.9	.4	.3	.9	.0	.5	.1	77.0	.5	.7
20	.4	.5	71.9	.4	.4	.9	.0	.5	.0	76.8	.4	.7
21	.4	.6	72.0	.4	.4	76.9	.0	.5	.0	.8	.3	.7
22	.4	.6	.0	.4	.5	77.0	.0	.5	.0	.7	.2	.6
23	.3	.7	72.0	.5	.5	.0	.0	.4	.0	.6	.0	.6
24	.2	.7	71.9	.6	.5	.1	.1	.4	.0	.6	74.0	.5
25	.2	.6	.9	.7	.6	.2	.1	.4	.0	.5	73.9	.4
26	.2	.6	.9	.8	.6	.2	.1	.4	.0	.4	.8	.4
27	.1	.6	.9	.8	.7	.2	.1	.4	.0	.4	.8	.3
28	.1	71.6	71.9	.9	.7	.2	.2	.4	.0	.5	.9	.3
29	.1	......	72.0	73.9	.8	.3	.2	.3	78.0	.4	.9	.4
30	.2	......	.1	74.0	.9	77.3	.2	.4	77.9	.4	73.9	.3
31	71.3	......	72.2	......	75.9	......	78.2	78.4	......	76.3	......	72.2

In the unsmoothed data, August 19, with 78.8°, is the warmest.

If the raw data are smoothed to hundredths as 7-day progressive means, we get August 21, with 78.50°, as a trifle warmer than any other date.

Thus, the three methods give three successive dates, August 19, 20, and 21, from which we may choose August 20 as the warmest date.

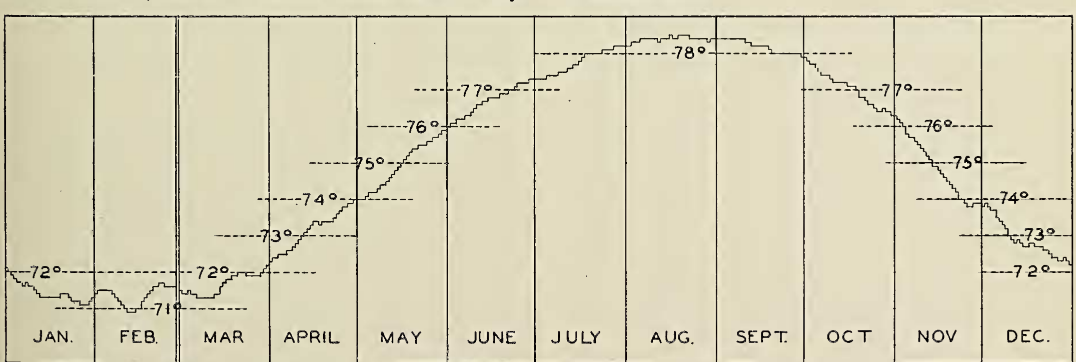

FIG. 2. Averages of daily mean temperature at Honolulu; smoothed as 7-day progressive means; 58 years, 1890 to 1947.

The 41-year data, reported on in 1943, smoothed to hundredths as 7-day progressive means, gave September 6, with 78.51°, as the warmest date. The 17-year data gave a run of 7 days with 78.6°, from August 16 through August 22. From these, August 19 may be taken as the warmest date, and agreeing well with the August 20 date from the 58-year graph.

The 36-day long "plateau" of Figure 2 was subjected to further study by means of 18 graphs of 7-day progressive means, from July 15 through September 25, for the 18 years from 1931 through 1948. On these graphs there were found a total of 43 dates which either had the maximum temperature for the year in question or were tied for the maximum. They ranged from as early as July 22 to as late as September 25, a range of 65 days. The mean and median dates were both August 23. The standard deviation was 14.5 days, a large value that implies uncertainty as to the date of the mean. Inspection of the 18 graphs showed a great variation—some were relatively smooth and some rather "wavy"; some showed a single maximum and some showed several scattered dates tying for the maximum; and, of course, the dates of the maxima varied greatly as described above.

The plateau of 36 days duration contrasts strongly with the wavy curve of the first months of the year. The difference is thought to be due to differences in the altitudes of the noon sun. In winter the altitude of the noon sun decreases steadily to a minimum about December 21 and then increases steadily. But in summer the noon sun on two occasions crosses the zenith of Honolulu, in 21° 18′ N. Lat. The noon sun is nearest the zenith about May 26 and again about July 16. On about June 21 the noon sun is 2° 9′ north of the zenith, and it is the same amount south of the zenith about May 16 and July 26. Thus for the period of 71 days between these two dates the noon sun is very high. During this time, also, the length of the daylight day varies only 17 minutes—that is, from 13 hours and 9 minutes to 13 hours and 26 minutes. Thus there is a long period in which the insolation is not only strong but is very uniform, which uniformity may well explain the plateau or long sequence of days of uniformly high average temperatures.

LAGS

If we select February 13 as the coldest date, we find that it falls 54 days after the winter solstice. Similarly, August 20 falls 60 days after the summer solstice. These dates divide the year into somewhat unequal parts. It takes 188 days to warm up from the coldest to the warmest date, but only 177 days to cool down again.

The most rapid cooling is from November 1 to November 26, during which time the 7-day progressive means drop 2.5°, from 76.3° to 73.8°, or at a rather steady rate of a tenth of a degree per day.

A longer period of fairly steady warming up extends from March 28 to June 15, with a rise of 4.8°, from 72.0° to 76.8°, in 78 days, or at a rate of about 0.06° per day. This period of rising temperature is not as steady or as rapid as the drop in November, but a short period of 10 days, from May 10 to May 20, gives a steady rise of about a tenth of a degree per day.

CONCLUSIONS

We have been considering only one element of the weather, namely the physical temperature, but the impression that the human animal gets of temperature is strongly modified by the effects of air movement and of humidity.

It appears that, on the average, the coldest date is February 13 and the warmest date is August 20. But, despite the alleged monotonous uniformity of Hawaiian weather, the dates of warmest and coldest temperature in any one year may come as much as a month earlier or later than the average dates. It also appears that the cold season may include several irregular fluctuations of temperature.